

OPTICALLY ADDRESSABLE DISPLAY AND METHOD DRIVEN BY POLARIZED EMISSIONS

FIELD OF THE INVENTION

5 The invention is in the optically addressed display field. The invention is applicable to a wide range of devices using displays including, for example, home entertainment monitors and large outdoor stadium displays.

BACKGROUND OF THE INVENTION

10 Optical display technology continues to evolve competitively. Displays are being developed that are larger, thinner, and yield higher resolutions. Optically addressable displays ("OAD") allow for larger display sizes while maintaining a minimal amount of circuitry. The circuitry is kept at a minimum because the OAD's pixel elements, which usually contain LEDs activated by
15 receptors, are responsive to light and not electronic signals. The complicated wiring of each pixel that allows it to be activated is eliminated.

 The current techniques used to deliver color information to OADs have various drawbacks such as alignment and cost. One technique commonly used is an infrared raster addressing scheme. Each pixel element's color receptor is
20 located and addressed with an IR beam. However, because each receptor is responsive to the IR beam, alignment becomes an issue. The IR beam needs to be precisely aligned to ensure that only the appropriate receptor is addressed at the right time. If the IR beam is misaligned with the color receptors the entire display could shift to an incorrect color set. Additionally, a less severe
25 misalignment could cause the image on the display to exhibit a color shift.

Another technique for delivering color information is frequency modulation. The frequency of the IR beam is varied at the IR source and projected onto the receptor circuits of the pixel elements. The receptor circuits are responsive to one of the varied frequencies of the IR beam. The
5 corresponding pixel is activated only when the receptor receives its varied frequency. Alignment is less of a problem with this technique because each color circuit would be activated only when the correct frequency of the IR beam is received by the receptor. However, this technique is costly and complicated. Every color circuit would have different components resulting in increased costs.
10 The frequency modulation hardware would also increase the cost and complexity on the projector end.

Utilizing different wavelengths of light for each color is also another technique used for delivering color information. A red, green, and blue pixel each includes a receptor that is unique from the other two colored pixels. A
15 different wavelength of light is projected onto the receptors for each of the multiple colors. The receptors contain narrow optical filters that allow the unique selection of the color channels. As with the frequency modulation technique alignment is less of a problem, however, these optical wavelength filters can be very expensive. There remains a need for a cost-efficient optically addressable
20 display system that overcomes the alignment issue.

SUMMARY OF THE INVENTION

An optically addressable display of a preferred embodiment uses emissions having plural polarizations to define a corresponding number of color channels. A data encoder applies data for each of the color channels to corresponding ones of the plural polarizations. The display also includes a plurality of pixels for producing a color display. There is a plurality of receptors including at least one receptor for each pixel. The receptors activate pixels depending upon which, if any, of the plural polarizations is received.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating a preferred embodiment of an optically addressable display system.

FIGs. 2A-2D are schematic views of an exemplary circular multi-segment polarization filter;

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FIGs. 3A-3F are schematic views of an exemplary circular linear filter polarization filter;

FIG. 4 is a graph illustrating an exemplary polarization phase sequence of an emission;

FIGs. 5A-5C are schematic views of an exemplary data encoder;

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FIGs. 6A-6E are graphs illustrating an exemplary timing scheme of the data encoder and polarization filter of FIG. 1;

FIG. 7 is a conceptual physical layout of an exemplary multi-color pixel;

FIG. 8 is a schematic diagram illustrating an exemplary optically addressable display device;

FIG. 9 illustrates another exemplary embodiment data encoder; and

FIGs. 10A – 10C illustrate another exemplary embodiment optically addressable display device.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to optically addressable displays and methods for delivering color information to optically addressable displays. In the invention, polarized visible or non-visible emissions define multiple color channels. In an exemplary embodiment, sequentially polarized emissions produce multiple color channels where data is delivered sequentially for separate channels. In another embodiment, polarized emissions define multiple color channels simultaneously. Data is added to the polarized emissions by a data encoder. Preferably, the polarized emissions encompass the entire data encoder. In preferred embodiments, the data encoder is realized with an array of digital light processing mirrors. Depending on the applied data, the data encoder's elements selectively reflect the emissions onto corresponding pixels. In preferred embodiments, a multi-color pixel corresponds to each mirror. With the polarization phase encoding, the corresponding mirror encodes the multiple colors of the pixel.

The invention will now be illustrated with respect to exemplary embodiment devices. Methods of the invention will also be apparent from the following discussion. In describing the invention, particular exemplary devices will be used for purposes of illustration. Illustrated devices may be

schematically presented, and exaggerated for purposes of illustration and understanding of the invention.

In FIG. 1, an exemplary optically addressable display 10 includes an emission source 12 that generates emissions 14. A polarization filter 16 is
5 disposed in the path of the emissions 14 to sequentially polarize the emissions into sequentially polarized emissions 18. Sequential polarization, as used herein, means that the polarization changes over time, providing the opportunity to define multiple channel encoding over a period of time. A linear polarization over a 360° rotation is preferred as a straightforward implementation, while
10 polarization may also be changed sequentially to particular polarization phases that are maintained for a period of time. The latter polarization filter is a more complicated approach to realize in practice.

The polarization filter might be realized optically, by lensing, for example. However, other methods of polarization are also possible, including sequential
15 and simultaneous methods. The simultaneous methods permit polarization to encode multiple color channels and the data for the multiple color channels is sent at the same time. For example, liquid crystals can perform a polarization function and do not require sequential timing in addressing the display. Another possibility is the omission of a filter in favor of an emission source that changes
20 polarization, or multiple sources that have different polarizations. In some embodiments, there are multiple emission sources for each pixel. For example, the emission source 12 may also be comprised of multiple sources, each providing a distinct polarized emissions. As an additional example, there might

be an emission source having a distinct polarization only for each color channel. Sequential or simultaneous polarization might then be utilized.

Considering again the FIG. 1 embodiment, a data encoder 20 applies data to the sequentially polarized emissions 18 on a pixel-by-pixel basis. In
5 embodiments of the invention a pixel 22 is a multi-color pixel, and the data encoder applies data to each pixel through the sequentially polarized emissions 18. Pixel, as used herein, refers to the resolution of the encoder 20. For example, in the case of a digital mirror device, each mirror defines the resolution of a pixel. Physically, that pixel may comprise any number of physical elements
10 that can respond to a polarized emission and produce a display. In large or projected display systems, a mirror might address three, four or another number of colored LEDs, for example. In addition, the mirror might also be addressing groups of colored LEDs, e.g., 50 red LEDs, 50 green LEDs and 50, blue LEDs. Here, and in other places, the number of colors and the number of physical
15 elements is provided only by way of example. Color science and management may change from implementation to implementation, but the polarization encoding of the invention may still be applied, as artisans will appreciate.

Whether or not a pixel is activated is determined by the data encoder, while the color activated for each multi-color pixel depends upon the state of the
20 polarized emissions 18. The data encoder 20 therefore combines with the polarization filter 16 to present data including an on/off state, intensity and color to each pixel 22. Intensity is controlled, for example, by the encoder controlling a duration for activating a pixel during a particular polarization phase. As an example, the red portion of a multi-color pixel may be made active for half of the

corresponding red encoding polarization phase. This produces a lower intensity than if the red portion is held active for three quarters of a corresponding red encoding polarization phase. In addition, the data could encode timing. As an example, using the end of a polarization phase to illuminate a particular color in a pixel can produce a mixing effect as the physical element producing the particular color has a decay that will overlap the display of a physical element producing a different color during a different polarization phase.

The emission source 12 preferably generates non-visible emissions to avoid interfering with the display by pixels 22. Infrared (IR) emissions are suitable. However, an emission source 12 that generates visible spectrum emissions, such as a laser, may be used effectively, as well.

An exemplary embodiment of the polarization filter 16 is a spinning circular multi-segment filter 28 as shown in FIGs. 2A – 2D. The multi-segment filter 24 contains multiple segments 26, 28, and 30. The multiple segments are polarized to respective phases θ_1 , θ_2 , and θ_3 . Exemplary phases θ_1 , θ_2 , and θ_3 are 0 degrees, 120 degrees, and 240 degrees, but it is understood that the embodiment is not restricted to these specific phases. Each of these phases corresponds to a color data channel. For example, 0 degrees may correspond to red, 120 degrees to green, and 240 degrees to blue. The multi-segment filter 24 rotates, as illustrated by FIGs. 2B-2D. The rotation causes the emissions 14 to become sequentially polarized as they pass through the multi-segment polarized filter 24. The data encoder 20 is synchronized to the sequentially polarized phases so that it can encode the proper colors at the proper polarization phases. However, the synchronization may be electronically

altered. This could, for example, be used to compensate for physical effects that alter the polarization.

One complete rotation cycle of the multi-segment filter 24 brings each segment 26, 28, and 30 of the multi-segment filter 24 into the pathway of the emissions 14. When a segment such as 26, encounters the emissions 14, the emissions 14 become polarized with respect to the phase θ_1 of segment 26, as shown in FIG. 2B. The multi-segment filter 24 continues to rotate bringing segment 28 into the pathway of the emissions 14. The emissions 14 become polarized with respect to phase θ_2 of segment 28 as it passes through segment 28, as shown in FIG. 2C. The final segment 30 will encounter the pathway of the emissions 14 as the multi-segment filter 24 completes one rotation. As the emissions 14 pass through segment 30, the emissions 14 become polarized with respect to θ_3 of segment 30, as shown in FIG. 2D. Continued rotation allows for the emissions 14 to be polarized in a sequence of phases resulting in the sequentially polarized emissions 18.

Alternatively, the polarization filter 16 may also be a circular linear filter 32, as shown in FIGs. 3A–3F. Although the linear filter 32 is not comprised of discrete segments like the multi-segment filter 24, sequentially polarized emissions 18 are still produced. As the linear filter 32 rotates, the polarization phase changes continuously as shown in FIGs. 3A-3F. As the emissions 14 pass through the rotating linear filter 32, sequentially polarized emissions 18 are produced. The rotation of the linear filter 32 produces phase peaks, for example, at 0 degrees, 120 degrees, and 240 degrees. The point of rotation as shown in FIG. 3A will cause the emissions 14 to become polarized with respect

to θ which is, for example, a peak of 0 degrees. As the linear filter 32 rotates in a counter-clockwise direction θ changes as shown in FIG. 3B and the emissions 14 will become polarized with respect to a peak of 120 degrees. The polarization angle θ continues to change as shown in FIG. 3C and the emissions 14 are polarized with respect to a peak of 240 degrees at this rotation point. As an example, the sequentially polarized emissions 18 can be assigned with respect to bands near the peaks of 0 degrees, 120 degrees, and 240 degrees for the color data channels for red, green, and blue, respectively. These channels may also be respectively assigned bands around the corresponding peaks that are 180 degrees out of phase, namely peaks at 180 degrees, 300 degrees, and 60 degrees.

Referring now to FIG. 4, the phase peaks that correspond to the color data channels (R)ed, (G)reen, and (B)lue are shown. The polarized emissions 18 polarized with respect to the 0 degree (34) and 180 degree (40) peaks of the linear filter 32 correspond to the red color data channel. The polarized emissions 18 polarized with respect to the 60 degrees (36) and 240 degree (42) peaks of the linear filter 32 correspond to the blue color data channel. The polarized emissions 18 polarized with respect to the 120 degree (38) and 300 degree (44) peaks of the linear filter 32 correspond to the green color data channel. It is understood that the present invention is not limited to these specific associations of the color data channels with these specific phases.

Referring back to FIGs. 3A-3F, the sequential polarization of the emissions 14 will be described. As the linear filter 32 begins to start a counterclockwise rotation cycle, the emissions 14 are polarized with respect to

the red color data channel at the 0 degree peak, as shown in FIG. 3A. The emissions 14 are polarized with respect to the blue color data channel at the 60 degree peak as the linear filter 32 completes 1/6 of the rotation cycle, as shown by FIG. 3D. The emissions 14 are polarized with respect to the green color data channel at the 120 degree peak as 1/3 of the rotation cycle is completed, as shown by FIG. 3B. When the linear filter 32 rotates halfway through one cycle, the emissions 14 become polarized with respect to the red color data channel again at the 180 degree peak, as shown by FIG. 3E. At 2/3 of a rotation, the emissions 14 are polarized with respect to the blue color data channel again at the 240 degree peak, as shown by FIG. 3C. The emissions 14 are polarized with respect to the green color data channel again at the 300 degree peak upon completion of 5/6 of one rotation cycle, as shown by FIG. 3F. The 300 degree peak completes the sequential polarization of one rotation cycle of the linear filter 32. Similar cycles are produced by a clockwise rotation.

FIG. 5A illustrates a preferred embodiment of the data encoder 20, which is a digital micro-mirror device ("DMD") 46, such as those available from Texas Instruments. More generally, a DMD 46 contains an array 48 of mirrors 50 that correspond to the plurality of pixels 22. In a preferred embodiment, each mirror 50 corresponds to a single pixel 22. The array 48 of mirrors 50 is preferably completely encompassed by the sequentially polarized emissions 18, as shown in FIG. 5B. A raster scan is also possible, but having the sequential emissions 18 encompass the DMD 46 eliminates the potential for misalignment problems between the source 12 and DMD 46. Each mirror 50 is capable of moving independently of the others. The independent movement allows the mirrors to

selectively reflect a portion of the sequentially polarized emissions 18 to its corresponding pixel. In certain embodiments, a mirror 50 is controlled to be turned away or toward a corresponding multi-color pixel for each of multiple separate polarization phases, depending on applied data. For a particular color display, a pixel requires a corresponding mirror 50 to be toward it and a corresponding state of the sequentially polarized emissions.

An on state is defined by a mirror 50 directing sequentially polarized emissions 18 to a corresponding pixel 22. An off state is defined by the mirror 50 reflecting sequentially polarized emissions 18 away from a pixel, and preferably to a light absorber 52 (FIG. 5C) if the emissions are in the visible range. The mirrors 50 may also be dithered to control intensity and timed to produce color mixing effects owing to the decay cycle of physical elements, e.g., LEDs used for color display in the pixels 22.

FIG. 5C shows the mirrors 50 in their on and off states. For illustration purposes, FIG. 5C shows three mirrors 50a, 50b, and 50c. The sequentially polarized emissions 18 in this illustration correspond to the red color data channel. Sequentially polarized emissions 18 encompass all of the mirrors 50a, 50b, and 50c. With data applied, pixels 22a and 22c are red as a result of the mirrors 50a and 50c directing polarized emissions corresponding to the red channel toward pixels 22a and 22c. Mirror 50b corresponds to a pixel 22b which is to display no red during the current duration of the red color channel according to data applied to mirror 50b.

The array 48 of mirrors 50 is timed with the phases of the polarization filter so that red data is applied during the red color channel, for example. This timing may be altered to produce display effects or to perform compensations.

FIGs. 6A-6E illustrate a preferred timing scheme of mirrors 50 for
5 embodiments of the invention where using a linear polarization filter and sequential polarization. FIG. 6A represents the filter before it starts to spin. FIGs. 6B-6E illustrate the timing of the mirrors 50 and the emissions for the red, green, and blue color data channels. Channels begin at points 54 and end after a period of time. Specifically, filter thresholds 56 create bands defined between
10 points 54 and 58 around emission peaks 60 that occur at different phases. For example, a red color channel is available in a band of emissions that result from a filter threshold 56, near and including the 0 and 180 degree peaks. Referring now to FIG. 6E, when one peak of the polarization phase has ended there is preferably a gap of time 62 before the next color data channel is encoded. The
15 gap 62 will prevent overlap in addressing two colors simultaneously.

Referring now to FIG. 7, an exemplary pixel 22 includes a red 64, a green 66, and a blue 68 light emitting diode ("LED") and corresponding receptors 70. Each receptor 70 includes a polarization filter 72 that is disposed over the receiving end 74 of the receptor 70. Receptors 70 of red pixels are responsive
20 to a corresponding polarization state, receptors of green pixels to another, and receptors of blue to another. Different polarization filters may be used for this purpose, or, as in FIG. 7, the orientation of a filter 72 may determine its response. Through the latter technique, a single type of rotationally sensitive filter 72 may be used for multiple colors. In a large, mass manufactured device,

this can reduce part count and provide significant cost savings. For example, the receptor 70 for the red LED 64 is positioned so that emissions polarized with respect to 0 or 180 degree bands are the only emissions that will pass through the polarized filter 72 on the receiving end 74 of the receptor. In this way, a multi-color pixel may be addressed by a single mirror 50.

Referring now to FIG. 8, a method of delivering color information to an optically addressable display will be described with respect to a preferred embodiment display. An infrared source 76 generates emissions 14 in the non-visible spectrum. The emissions 14 pass through the rotating multi-segment polarization filter 24. The segments 26, 28, and 30 of the filter 24 polarize emissions 14 to 0, 120, and 240 degrees, respectively. As the multi-segment filter 24 rotates in a counter-clockwise direction, the emissions 14 are sequentially polarized. The sequentially polarized emissions 18 are made uniform by an integrating rod 78, which might be placed prior to the filter 24 to avoid an altering of the polarization. A condensing lens 80 may be used to ensure coverage of the DMD 46. The emissions 18 encompass the array 48 of mirrors 50 on the DMD 46. The mirrors 50 are phase coordinated with the segments 26, 28, and 30. If segment 26 codes the red color channel, the DMD 46 activates only those mirrors 50 have red data during that cycle. A projection lens 82 focuses sequentially polarized emissions 18 directed by the mirrors 50 toward receptors of pixels 22.

In an alternative embodiment, as illustrated by FIG. 9, the data encoder 20 is an array of light masks 84, such as an LCD array. Each of the light masks 86 corresponds to one or more of the individual pixels 22. The light masks 86

may be phase matched with the sequentially polarized emissions 18, similar to the DMD as described above. A sequentially polarized emission 18 encompasses the entire array of light masks 84, and only the light masks 86a that have red data during that cycle will permit the polarized emissions 18 to
5 pass.

Another optically addressed display device 90 is illustrated in FIGs. 10A – 10C. In FIG. 10A, the display 90 includes an array of pixels 22 as in the other embodiments. The pixels 22, for example, are constructed as described with respect to FIG. 7. A data encoder 92 in the device 90 is an LCD shutter crystal
10 94. The LCD shutter crystal 94 receives three different beams 96a, 96b, 96c having distinct polarizations. Tri-color data is applied to the LCD shutter crystal 94, which responds by selectively blocking or passing one or all of the three different beams 96a, 96b, and 96c for each of the pixels 22 in the array of pixels. In this manner, color data can be simultaneously delivered to each of the
15 pixels 22, but the resolution of the LCD shutter crystal need not be higher than that of the pixels 22. A projecting lens 98 delivers data from an output side of the shutter crystal 94 to the pixel array. The shutter crystal 94 includes four prisms 94a, 94b, 94c, and 94d. LCD shutters 100a, 100b, and 100c are applied to respective input faces of the prisms 94a, 94b, 94c. The prism 94d serves to
20 output encoded data emissions. Each of LCD shutters 96a, 96b, and 96c encodes emissions of a different polarization and corresponding to a different color channel. The shutters have a resolution of the pixels 22. In this way, a pixel may receive data for the three color channels simultaneously as the data

encoder encodes each set of polarized emissions separately and then combines the data encoded emissions to be directed at the pixels 22.

While specific embodiments of the present invention have been shown and described, it should be understood that other modifications, substitutions
5 and alternatives are apparent to one of ordinary skill in the art. Such modifications, substitutions and alternatives can be made without departing from the spirit and scope of the invention, which should be determined from the appended claims.

Various features of the invention are set forth in the appended claims.